

THE USE OF TREE-MOUNTED ARTIFICIAL SHELTERS TO INVESTIGATE ARBOREAL SPIDER COMMUNITIES IN NEW ZEALAND NATURE RESERVES

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ABSTRACT. Spiders have been advocated as valuable bio-indicators of forest ecosystem “health.” However, the numbers and types of spiders that are recorded at a site will usually be highly dependent on the sampling method employed. The use of lethal, indiscriminate invertebrate sampling techniques is undesirable when investigating rare species, or sampling within areas of high conservation status. Therefore we used non-lethal artificial tree-mounted shelters to monitor arboreal spiders in nature reserves near Christchurch, New Zealand. After three months, over 60% of the shelters had been used by spiders, increasing to 91% after twelve months. There were significant differences in the numbers of spiders found in the shelters at the different sites. However, factors such as the species of tree the shelter was attached to, ground vegetation, and levels of incident light did not affect the likelihood of a shelter being occupied. The species composition of the spider faunas in those sites regarded as high quality forest remnants was dissimilar to the faunas found in the low quality reserves. However, although spiders were more abundant in the high quality sites compared with the poorest stands of woodland, they were not more species rich. The shelters are inexpensive and easy to manufacture and are useful for long-term non-lethal monitoring of spider communities. They also have good potential as a tool for studying spider phenology, population dynamics, behavior, and as a collection/carriage device for live specimens used in conservation translocations.

Keywords: Arachnida, Araneae, monitoring, refuges, spiders, trees

INTRODUCTION

Spiders have been advocated as valuable surrogate measures for biodiversity assessment (Clausen 1986; Marc et al. 1999; Cardoso et al. 2004) and have been investigated for use as bio-indicators in natural and agricultural ecosystems and to monitor the progress of ecological restoration (e.g., Wheeler et al. 2000; Willett 2001; Longcore 2003; Perner & Malt 2003). The use of spiders as indicators of land and air poisoning by industrial processes or from misuse of agrochemicals has also been addressed (e.g., Madden & Fox 1997; Hodge & Vink 2000; Horváth et al. 2001).

When investigating populations or assemblages of spiders, the sampling method used has obvious repercussions for the numbers

and type of spiders that are collected (Work et al. 2002; Duffey 2004; Jiménez-Valverde & Lobo 2005; Meissle & Lang 2005). Although broad spectrum techniques such as pitfall trapping and chemical fogging of trees can provide substantial catches of spiders, these indiscriminate lethal trapping methods can prove counter-productive when investigating nature reserves or taxa of conservation importance. Non-lethal survey techniques, such as timed hand searches and standardized foliage beating can prove valuable in these circumstances since the sampler can be selective in determining which taxa, if any, are killed for further examination.

Non-lethal standardized samples of invertebrate assemblages have also been obtained

using "shelter traps" or "artificial retreats" (see Southwood 1978). For epigeal species, these shelters tend to be in the form of "cryptozoa boards"; flat pieces of timber or ceramic tiles placed on the ground, under which spiders (and other invertebrates) can take refuge (Bowie & Frampton 2004; Hodge & Standen 2006; Lettink & Patrick 2006). For arboreal spiders, Roberts (1985) and Jones-Walters (1989) describe the use of "bark traps" consisting of corrugated cardboard or plastic "bubble wrap" tied around the trunks of trees, the corrugations mimicking the convoluted surface of the tree bark and providing refuge for trunk-dwelling invertebrates. This technique has been used in some quantitative studies of spider behavior and community structure (Duffey 1969; Curtis & Morton 1974) and also in applied studies examining the influence of air pollution on arboreal spider assemblages (Horváth et al. 2001).

The current investigation originated from using tree-mounted wooden shelters to monitor and translocate rare endemic orthopteran insects ("weta"; Anostostomatidae and Rhabdophoridae) in New Zealand nature reserves (Bowie et al. 2006). During the initial stages of the study, it was observed that the most common occupants of the shelters were spiders, including many with egg sacs and newly hatched spiderlings. It was decided to extend the investigation and continue to record the spiders residing in the shelters over the course of a year. This paper describes the numbers and types of spiders found, and examines whether various environmental factors (e.g., tree species, height, ground cover, etc.) affected shelter occupancy. The diversity and composition of the spider assemblages at each site were compared to establish whether these measures could be used to discriminate between high and low quality forest remnants and thus provide some indication of ecosystem "health" and of conservation/restoration success.

METHODS

The sampling methods have been described in detail in Bowie et al. (2006) but are given again here for clarity. The shelters were constructed from blocks of untreated pine wood (45 × 45 × 150 mm) cut with a 60° "roof" (Figure 1). A central groove (18 × 18 mm) was cut two-thirds down the length of the

block using a router. Transparent acetate was stapled over the groove as a window to enable the occupants to be viewed rapidly. Black polythene was then stapled over the window to prevent light from entering when the shelter was in position, and could be folded back to view any occupants when required. A plastic cover was nailed to the top of the shelter to reduce rain damage to the wood. The shelters were attached to trees using plastic-coated wire, so that the grooved side was firmly against the trunk of the tree. The height of the shelter from the ground was then recorded.

Fifty shelters were placed in each of six nature reserves in Canterbury, South Island, New Zealand: Hinewai Reserve (43.81687°S, 173.02254°E), Orton Bradley Park (43.67042°S, 172.71387°E), Quail Island (43.63103°S, 172.69008°E), Ahuriri Scenic Reserve (43.66375°S, 172.61782°E), Travis Swamp (43.48647°S, 172.68791°E) and View Hill (43.28676°S, 172.07572°E). These sites varied greatly in the plant species present and in the quality of the forest remnant. Quail Island is currently being ecologically restored and contained the poorest stands of native tree species, while Hinewai and Ahuriri are considered two of the finest forest remnants in Canterbury and have the most established and diverse stands of forest (Bowie et al. 2004, 2006; and refs. therein).

The shelters were attached to trees from August to October (spring) 2000 and checked at three-month intervals for 12 months. On the first three sampling dates, each shelter was scored for the presence/absence of adult and sub-adult spiders and their numbers recorded. The presence of egg sacs and batches of newly-hatched spiderlings were also recorded. On the final 12th month sampling date (spring 2001) all spiders were identified to species. Where possible this was done *in situ* but difficult specimens, juveniles and some voucher specimens were collected into 70% ethanol and returned to the laboratory to confirm identifications. Juveniles were assigned to a species if they could be confidently identified by unique non-genitalic characters and no other species of that genus were found at a particular site. Voucher specimens have been deposited in the Entomology Research Museum of Lincoln University, Canterbury, New Zealand. Nomenclature follows that of Platnick (2006).



Figure 1.—Female *Cambridgea* sp. with two egg sacs in a shelter at Tiravis Swamp.

During the summer sampling period, a number of environmental factors were measured for each shelter. These were: light intensity at the face of the shelter [Yokogawa lux meter, Yew 3281], moisture of the soil at the base of the tree [Hydrosense, Campbell Scientific, Australia], ground slope (using a clinometer), ground cover (i.e., percent area leaf litter, bare ground, vascular plants) and the depth of loose litter above firm soil. The effect of aspect was analyzed by classifying the ground slope and the shelters as facing north (315–44°), east (45–134°), south (135–224°) or west (225–314°). The effects of these various factors on the presence of spiders in a shelter (within each site and at any time dur-

ing the survey) were assessed using binary logistic regression or, for shelter aspect, the chi-square statistic.

RESULTS

Occupation of shelters.—Sixty-two percent of the shelters contained adult or subadult spiders after three months and the average level of occupancy increased gradually with time in the field (Table 1). Over the whole 12 month sampling period 91% of the 300 shelters contained live spiders on at least one occasion. Occupancy of the shelters varied significantly between the sites (Yates corrected $\chi^2 = 50.3$, $P < 0.001$, 5 *df*, based on presence of spiders in a shelter at anytime dur-

Table 1.—The proportion (%) of wooden shelters containing live spiders at each site on each sampling visit ($n = 50$; * = a small number of shelters were damaged by vandalism and contained zero spiders).

Time in field		Occupation of shelters (%)						Mean
Months	Season(s)	Ahuriri	Hinewai	OB Park	Quail Is.	Travis Sw.	View Hill	
3	Summer	76	68	72	28	66	62	62.0
6	Autumn	78	66	72	32	72	64	64.0
9	Winter	96	82	74	48	84*	52	72.7
12	Spring	88	88	92	40	78*	72	76.3
>12	All	96	100	100	64	94	92	91.0

ing the survey), with Quail Island shelters having consistently lower occupation than the other five sites (Table 1).

From 1200 shelter inspections, a total of 856 observations of live spiders were made. However, as the spiders were not marked it is not known whether some records represent repeat observations of the same individuals. The majority of occupied shelters (90%) contained only a single adult or sub-adult spider: there were 37 observations of two spiders together in a shelter and one observation each of three, four and five spiders cohabiting.

Factors affecting spider occupancy.—At each site, none of the environmental factors measured had a statistically significant effect on the likelihood of a shelter being occupied. There was also no association between occupancy and the direction the shelter was facing or the aspect of the ground slope.

Shelters were attached to a total of twenty-one tree species but there was no association between occupancy of shelters and tree species within each of the sites (analyzed using the G -statistic: $P > 0.1$ in all cases). From the high levels of occupancy observed it was apparent that shelters attached to all tree species used were acceptable to spiders. Differences in shelter occupancy on the same tree species occurred between sites. For example, shelters attached to kanuka trees (*Kunzea ericoides* (A.Rich.) J.Thompson) at Orton Bradley Park and Hinewai had 100% residency, whereas those at Quail Island, where occupation was lower in general, had spiders in only 50% of shelters.

The spider fauna.—A total of 243 spiders were recorded in the 300 shelters in the final (spring) sample, belonging to 21 species in 10 families (Table 2). Twelve species were represented by only a single specimen and only 11 of the 207 adults and sub-adults were

males. Other species were recorded in the shelters during the earlier samples but not found in the spring census. These were: *Eriophora pustulosa* (Walckenaer 1842) (Araneidae) at Quail Island and Travis Swamp, *Taieria kaituna* Forster 1979 (Gnaphosidae) at Ahuriri and Hinewai, and *Cambridgea peelen-sis* Blest & Vink 2000 (Stiphidiidae) at View Hill.

All of the species found are considered common in Canterbury, typically found on or around trees and foliage. Sixteen species are endemic to New Zealand, of which five are endemic to Canterbury and two endemic to Banks Peninsula (Forster & Wilton 1973; Blest & Vink 2000; see Table 2). An important finding was an adult male *Nuisiana arboris* (Marples 1959) (Desidae) in the winter samples at Orton Bradley Park, which had previously been known only from female specimens in New Zealand (Forster & Wilton 1973). *Neoramia janus* (Bryant 1935) (Ageniidae), *Theridion zantholabio* Urquhart 1886 (Theridiidae) and *Cambridgea ambigua* Blest & Vink 2000 (Stiphidiidae) laid numerous egg sacs in the shelters, many of which successfully produced spiderlings (Figure 1).

In terms of species composition, *Neoramia janus* was the dominant species contributing 42% of the spiders collected in the final sample, but was absent from both Quail Island and Travis Swamp. *Theridion zantholabio* was the most widespread species, being the only species to be found at all six sites. *Porrhothele antipodiana* (Walckenaer 1837) (Hexatheliidae) and *Cambridgea quadromaculata* Blest & Taylor 1995 (Stiphidiidae) were only found at the two least modified sites, Hinewai Reserve and Ahuriri Scenic Reserve. Conversely, *Achaearanea veruculata* (Urquhart 1886) (Theridiidae) and *Cambridgea ambigua* were

found in high numbers but did not occur at these two high quality reserves.

The numbers of spiders recorded at the six reserves in the final spring sample reflected the overall patterns in occupancy, with Quail Island having fewer spiders than the other five sites ($\chi^2 = 15.6$, $P < 0.025$, 5 *df*). Orton Bradley Park recorded the greatest number of individuals, largely due to a seemingly disproportionate number of the theridiid *Theridion zantholabio*. The six reserves differed greatly in their degree of spider diversity and, although Quail Island had the lowest occupancy levels and smallest number of spiders, it had the greatest species richness, lowest dominance index and the highest Shannon-Wiener diversity index (Table 2). Indeed, four species were recorded only from Quail Island; *Clubiona huttoni* Forster 1979 (Clubionidae), *C. peculiaris* L. Koch 1873 (Clubionidae), *Hemicloea rogenhoferi* L. Koch 1875 (Gnaphosidae) and *Steatoda capensis* Hann 1990 (Theridiidae) (the latter two are introduced species). The two reserves considered to be the highest quality remnants, Ahuriri and Hinewai, actually had the lowest species richness, with only four and six species respectively.

Because only eight of the 21 species occurred at more than one location, comparing the "similarities" of the faunas is problematic. However, it is probably valid to regard the faunas found at the two high quality reserves, Ahuriri and Hinewai, as the most similar, as all four of the species found at Ahuriri also occurred at Hinewai, and both were dominated to a similar degree ($\approx 65\%$) by *Neoramia janus*. The spider assemblages found at the two poorest quality reserves, Quail Island and Travis Swamp, were disparate from those at the other four sites: they did not contain *N. janus* and both sites had a number of species that were not found at any of the other reserves.

DISCUSSION

Spiders readily inhabited the artificial shelters used in this study and their suitability as a domicile for spiders was further confirmed by the production of egg sacs and the successful emergence of spiderlings. None of the environmental factors measured affected the likelihood of shelter occupancy, and there was also no effect of tree species on the numbers of spiders found (but see Curtis & Morton

1974). We found no effect of height of the shelter on the trunk of the tree, although the height profile we used was limited to that within easy reach (by humans) from the ground. Placement of shelters higher up the trunk, or in the canopy, might reveal differences in occupation or use by different species.

Only 5% of the adult and sub-adult specimens found in the spring sample were male. Curtis & Morton (1974), in a survey of bark-dwelling spiders in Scotland, also found a bias towards female specimens in their bark-traps, but this contrasted with the sex ratio of the spiders they collected from the bark itself which had a strong male bias. It appears that females tend to remain sheltered while the males have a greater tendency to roam the more exposed areas of the tree trunk, possibly to locate females (Foelix 1996). A comparison of the spiders recorded in the shelters with those found on the surrounding bark would be informative on this issue. Also, in addition to taking samples from the bark surface, actively sampling spiders by foliage beating or hand searching would make it possible to place the assemblage of shelter-residents into a context of the arboreal fauna as a whole.

As a survey technique, it is conceded that the numbers and diversity of spiders recorded in the shelters were low compared to what might have been achieved with similar effort using more conventional sampling techniques. Although the number of species recorded was small, the shelters provided records of species that have not previously been found during intensive faunal surveys of these reserves (e.g., Quail Island and Travis Swamp; Macfarlane et al. 1998; Bowie et al. 2004). Rarefaction analysis of the spring data has indicated that further monitoring of the shelters, or the placing out of more sampling units, would likely locate further species at most sites, although it is possible that the shelters represent a novel habitat that is only ever likely to be used by a limited number of tree-dwelling species. The value of the shelters might lie in providing a non-lethal sampling method that complements other survey techniques within a particular site, and provides a standardized measure to compare resident spider faunas between sites.

The results of the spring survey allowed some interesting comparisons to be made.

Table 2.—Adult, sub-adult and immature spiders collected from 50 tree-mounted shelters at each site in the spring visit. ^E = endemic, ^I = introduced, ^C = Canterbury endemic, ^B = Banks Peninsula endemic.

		Ahuriri	Hinewai	OB Park
Agelenidae	<i>Neoramia janus</i> (Bryant 1935) ^{E, C}	29	30	22
	<i>Neoramia setosa</i> (Bryant 1935) ^{E, B}	—	—	1
Amphinectidae	<i>Maniho ngaitahu</i> Forster & Wilton 1973 ^{E, B}	—	1	—
Clubionidae	<i>Clubiona convoluta</i> Forster 1979 ^E	—	—	—
	<i>Clubiona huttoni</i> Forster 1979 ^E	—	—	—
	<i>Clubiona peculiaris</i> L. Koch 1873 ^E	—	—	—
Desidae	<i>Badumna insignis</i> (L. Koch 1872) ^I	—	—	—
	<i>Matachia</i> sp. ^E	—	—	—
	<i>Nuisiana arboris</i> (Marples 1959) ^E	—	—	3
Gnaphosidae	<i>Hemicloea rogenhoferi</i> L. Koch 1875 ^I	—	—	—
	<i>Taieria erebus</i> (L. Koch 1873) ^E	—	—	—
	<i>Gnaphosida</i> sp.	—	—	1
Hexathelidae	<i>Porrhothele antipodiana</i> (Walckenaer 1837) ^E	7	4	—
Orsolobidae	<i>Orsolobidae</i> sp. ^E	—	1	—
Salticidae	<i>Trite auricoma</i> (Urquhart 1886) ^E	—	—	—
Stiphidiidae	<i>Cambridgea ambigua</i> Blest & Vink 2000 ^{E, C}	—	—	—
	<i>Cambridgea quadromaculata</i> Blest & Taylor 1995 ^{E, C}	2	5	—
Theridiidae	<i>Achaearanaa veruculata</i> (Urquhart 1886)	—	—	7
	<i>Rhomphaea</i> sp.	—	—	1
	<i>Steatoda capensis</i> Hann 1990 ^I	—	—	—
	<i>Theridion zantholabio</i> Urquhart 1886 ^E	6	5	22
	Total Spiders	44	46	57
Trap occupancy (%)	88	88	92	
Species Richness	4	6	7	
Dominance, d	0.66	0.65	0.39	
Shannon-Wiener, H'	0.98	1.14	1.36	

Quail Island is currently undergoing vigorous ecological restoration, with mature, native trees being few in number (Bowie et al. 2004) and this inferior quality of habitat was reflected in consistently low numbers of spiders being found and a spider assemblage with a very different composition from those found at the other sites. However, also of interest was that supposed high quality reserves at Ahuriri and Hinewai had the lowest number of species in the spring spider assemblages and that the species richness and species diversity at Quail Island were the highest of all six sites. This highlights a common problem when using summary diversity indices of animal assemblages to rank sites in terms of conservation value. It is sometimes not a case of *how many species* occur at a site but *which species* that provides the most sensible focus for site comparison.

The absence of some of the commoner species at Quail Island raises another potential use for the shelters: that of translocation of species between sites for conservation pur-

poses. For example, *Neoramia janus* was absent from Quail Island and Travis Swamp, the two most disturbed reserves, but was common in the other four sites. This species produced numerous egg sacs and batches of spiderlings within the shelters that could be used to establish populations in new locations. The animals could remain resident in the shelters during the transfer; the wooden shelters form a safe means of carriage for the animals and would likely reduce the incidence of transit mortality. By restricting the size of the entrance, predators such as rodents can be barred from entering the shelters.

The shelters have a number of other advantages over conventional (lethal) sampling methods. Regular inspection of the shelters can be used to monitor prey species and the rate of capture and, as there was generally only a single individual found in each shelter, there is potential for examining territoriality and the incidence of aggressive behavior towards non-residents. The shelters provide a method for investigating the phenology of the

Table 2.—Extended.

Quail I	Travis S	View H	Total	Adult	Sub adult	Immature
—	—	19	100	87♀	3♀ 4♂	6
—	—	—	1	1♀	—	—
—	—	—	1	1♀	—	—
—	1	—	1	1♀	—	—
1	—	—	1	1♀	—	—
1	—	—	1	1♀	—	—
—	1	—	1	1♀	—	—
—	—	1	1	1♀	—	—
—	—	4	7	4♀	—	3
1	—	—	1	1♀	—	—
—	—	1	1	1♀	—	—
1	1	—	3	—	1♀	2
—	—	—	11	8♀	1♀	2
—	—	—	1	1♀	—	—
—	1	—	1	1♀	—	—
1	24	6	31	23♀ 1♂	1♂	6
—	—	—	7	4♀	1♀	2
9	5	3	24	24♀	—	—
—	—	—	1	1♀	—	—
2	—	—	2	2♀	—	—
9	1	3	46	25♀ 1♂	1♀ 4♂	15
25	34	37	243	191	16	36
40	78	72	76			
8	7	7	21			
0.36	0.71	0.51	0.41			
1.58	1.05	1.48	1.88			

spiders in terms of temporal patterns in abundance and the production of egg sacs and spiderlings. Also, by marking individuals and visiting sites more regularly, there is the opportunity of obtaining information on individual mortality, site fidelity and migration.

In summary, these simple tree-mounted artificial shelters offer many opportunities for non-lethal study of arboreal spiders. In addition to providing a tool for long-term monitoring to evaluate the success of conservation management and site restoration, they can also be used to investigate various aspects of spider population dynamics, life history and behavior, and have good potential as a means of carriage during the translocation of species as part of ecological restoration programs.

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